GLOBAL CLIMATE COALITION • GROWTH IN A GLOBAL ENVIRONMENT • GCC

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BACKGROUNDER

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Climate Models: Shortcomings and Limitations

General Circulation Models

General circulation models (GCMs) are computer representations of global climate. They are based on mathematical equations derived from our knowledge of the physics that govern the Earth-atmosphere system. By definition, "climate" encompasses a vast number of factors (cloud cover, air and ocean temperatures, rain and snowfall, air and ocean currents, barometric pressure, atmospheric composition, etc.). These models are far from perfect, however. Policymakers should be aware of the limitations of computer models and recognize that while these models are useful tools for scientific research, they are not yet reliable enough to serve as the basis for multi-billion dollar public policy decisions.

Important Weaknesses in GCMs

The IPCC and the GAO have recently identified several important limitations associated with GCMs which clearly indicate that GCMs are not yet ready for use by policymakers. The IPCC has identified 5 major areas of weaknesses in GCMs:

- Poor model representation of cloud processes.
- A coarse spatial resolution (i.e., the grid-scale is too large).
- Problems in the parameterization of regional and local atmospheric processes.
- Generalized topography, disregarding some locally important features.
- A simplified representation of land-atmosphere and ocean-atmosphere interactions. (WGII FSM (Chapter 26, Technical Guidelines), section 6.5.3).

Until these weaknesses are significantly resolved, it is clear that policymakers will be hard pressed to rely on GCM output for policy decisions. The probability that the current output is misleading, or totally incorrect, is simply too high. Key limitations include:

- **Incomplete or inadequate quantification of processes affecting climate.**

  "Specifically, they have not been able to uniquely and quantitatively distinguish the effects of higher concentrations of greenhouse gases from the effects of other factors that can change the

climate. Such factors include natural fluctuations in the global climate system, increases in atmospheric ozone, air pollution, and aerosols emitted into the atmosphere from volcanic eruptions." (GAO, 1995, page 6).

- **Inadequate representation or inclusion of feedback mechanisms.**

  "GCMs include many of the most important feedback mechanisms, such as vegetation, water vapor, ice cover, clouds, and the ocean. However, the models do not yet adequately represent the interactions of these mechanisms with greenhouse gases. Such interactions can amplify, dampen, or stabilize the warming produced by increased concentrations of greenhouse gases." (GAO, 1995, page 8).

It is clear that *feedback mechanisms* (the interaction between the various components of the atmosphere) in GCMs have critical implications for policymakers. The net effect of feedbacks, from a policy viewpoint, is to determine whether a GCM indicates greenhouse gas emissions will be serious or benign. Clearly, the inadequate representation of feedbacks in climate models seriously undermines the usefulness of GCMs for policy purposes. Hence, until climatic feedbacks *are* adequately represented, policymakers should not rely on GCMs.

- **Insufficient computer power**

  "Insufficient computer power affects the accuracy of GCMs' estimates because even the most powerful computers are limited in their ability to store and analyze the vast quantity of data required to accurately simulate changes in the global climate. Modelers have tried to overcome these limitations by introducing assumptions into their models that deliberately oversimplify some operations in order to free the GCMs capacity and time for other, more critical operations." (GAO, 1995, pg 8-9).

The "simplification" of science by introducing assumptions designed simply to increase computational efficiency, raises serious questions about the accuracy of the final result. It is certainly possible that these "simplifications" accomplish their intended purpose (i.e., achieving a reasonable computational speed) while sacrificing the one thing that policymakers really need--an accurate theoretical projection of future climate. The presence of these simplifications, and our current lack of understanding about how they affect projections of future climate, limit the reliability of these projections for policy making purposes.

- **Inability to reliably project regional changes in climate.**

  "Still another limitation affecting the accuracy of GCMs' estimates is the relatively large size of the grids into which the models divide the earth. These grids typically cover an area about the size of South Carolina. Although their use enables GCMs to depict larger-scale regional effects in relatively large homogeneous regions, it does not allow modelers to incorporate detailed regional features. Consequently, the use of large grids prevents the models from accurately forecasting climatic changes for smaller, less homogeneous regions." (GAO, 1995, pg 9).

The IPCC stated the problem this way:

> *"GCM outputs, though physically plausible, often fail to reproduce even the seasonal pattern of present-day climate observed at a regional scale. This naturally casts some doubt on the ability of GCMs to provide accurate estimates of future regional climate. Thus GCM outputs should be treated, at best, as broad-scale sets of possible future climatic conditions and should not be regarded as predictions. (WGII FSM (Chapter 26, Technical Guidelines), section 6.5.3).*

From a policy perspective, projections of regional climate change are *the* most important output of climate models. Yet, it is clear that policymakers can have little confidence in regional climate change projections. In fact, the IPCC recently stated:

> *"Confidence is higher in the hemispheric-to-continental scale projections of coupled atmosphere-ocean climate models than in the regional projections, where confidence remains low." (IPCC Synthesis Report, paragraph 2.9).*

This limitation is critical, since it is potential changes in regional climate which are the basis for virtually all of the impact projections regarding greenhouse gas emissions. The question is naturally raised: If policymakers can have little or no confidence in regional climate change projections, then shouldn't policymakers also have low confidence in any resulting impact projections? Clearly, policymakers should not make multi-billion dollar decisions which are based on impact projections in which scientists, at best, can only express "low confidence".

Improving the Models

General circulation models, particularly regional climate projections, must be improved substantially before policymakers should base decisions on the scenarios they generate. Improvements are needed in several major areas of ongoing research, including the following:

Parameterization: Current parameterization (a mathematical estimate of how natural processes work) schemes are a major source of uncertainty. Improvements are needed in two areas: a) parameterization of cloud formation processes and b) understanding of interactions among the different parameterization schemes being used and portability of parameterization schemes between GCMs. A great deal of testing and development in this area is needed.

> *"At the present time, weaknesses in the parameterization of cloud formation and dissipation are probably the main impediment to improvements in the simulation of cloud effects on climate....There is a great need for observations of cloud-scale dynamics and of the radiative properties of clouds, so that the parameterizations of the physical processes can improve." (WG1 FSM, section 6.7.1.1).*

> *"While a given parameterization scheme may perform well in "off-line" tests, interactions with other parameterizations and with dynamics may not result in an improved simulation in a coupled model. A particular scheme may also perform well in one model but perform poorly when used in another model." (WG1 FSM, section 5.5).*

Paleoclimate Research: Although still inadequate for policy purposes, current GCMs are much improved from those that existed only a few years ago. Still, much work remains to be done to improve confidence in climate projections to the point that they can be relied upon by policymakers. In this regard, the IPCC has made it clear that priority should be given to improving the paleoclimatic data base. Without a significant improvement in paleo data, many uncertainties regarding climate change are unlikely to be resolved.

> *"To build confidence in the decade-to-century time-scale natural variability simulated by models, there is a need to compare model attempts to mimic the climate of the past 1000 years, with variability estimates from paleoclimatic data with comparable time resolution." (WG1 FSM, section 11.7).*
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> *"Without a better paleoclimatic data base for at least the past millennium, it will be difficult to rule out natural variability for recent observed changes, or to validate coupled model noise estimates on century time scales." (WG1 FSM, section 8.3.2)*
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> *"Unless paleoclimatic data can help to 'constrain' the century time scale natural variability estimates obtained from CGCMs, it will be difficult to make a convincing case for the detection and attribution of an anthropogenic climate change signal." (WG1 FSM, section 8.3.3.3)*

For these reasons, the GCC supports a coordinated international research program, the continuation of U.S. climate research efforts ($1.8 billion requested for FY 1995), in addition to independent and industry sponsored research. GCC also supports activities to reduce greenhouse gas emissions that make sense in their own right, thus continuing sound business practices that will lead to more efficient use of energy.

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The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

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